

25 September 1969

Materiel Test Procedure 6-2-065
Electronic Proving GroundU. S. ARMY TEST AND EVALUATION COMMAND
COMMODITY ENGINEERING TEST PROCEDURE

3484

DATA TRANSMISSION EQUIPMENT

1. OBJECTIVE

The objective of this materiel test procedure is to describe engineering test procedures necessary to determine the technical performance of special equipments which are required to condition digital data signals for transfer over military communication facilities and the capability of these media to transmit the information accurately, relative to criteria expressed in appropriate Qualitative Materiel Requirements (QMR), Small Development Requirements (SDR), Technical Characteristics (TC), and other applicable requirements or documentation.

2. BACKGROUND

The necessity for real-time exchange of digital data information among the dispersed elements of a military automatic data processing (ADP) system requires the use of all forms of communication media existing in the environment to provide the interconnecting paths. Since the characteristics of ADP signals and equipment, per se, are seldom wholly compatible with the characteristics of all types of transmission path, some form of interface equipment is required at the path terminals to attain compatibility.

An ADP-Communication interface may consist of a relatively simple device performing a single function or a complex aggregation of equipments performing several indirectly related functions. However, the basic function is to operate on digital data information in such a manner as to effect efficient transfer over conventional communication systems within the channel frequency spectrum available and the propagation constraints of the transmission media.

For the purpose of this document, "data transmission equipment" is defined as channel termination equipment employed for the sole purpose of data signal transformation. A selected communication channel terminated with this equipment is termed a "data channel". In other words, the role of a data channel is to convey information from a data "source" to a data "sink", without knowledge or manipulation of the information content of the data.

Various devices employed to accomplish the conversion process are generically termed "modems" (modulator - demodulator) and in the simplest form convert digital DC signals of the ADP equipments to/from digital AC (quasi-analog) signals for transmission over conventional circuits. A form of modem which performs the same basic function in telegraph/teletypewriter communications is exemplified in the long-time military standard TH-5 (TH-22) Telegraph Terminal. This device converts the DC telegraph/teletypewriter signals to frequency-shifted audio tones for transmission over standard voice channels at information transfer rates up to 75 bits (binary digits) per second.

A further discussion of data transmission equipment is given in Appendix

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A. of this MTP.

Since data transmission is a rapidly growing art, new equipment and systems will continue to evolve to meet data network requirements. Therefore, comprehensive engineering tests are necessary to determine technical performance adequacy with respect to specific requirements and existing equipment/systems.

3. REQUIRED EQUIPMENT

- a. Data transmission test facility (see Appendix B).
- b. Electronic laboratory.
- c. Land areas or sites suitable for installation of short and long range radio and cable systems.
- d. Signal/function generators.
- e. Noise generator.
- f. Frequency meter/electronic counter.
- g. Wave analyzer.
- h. Distortion analyzer.
- i. Noise measuring set.
- j. Transmission measuring set.
- k. RF field intensity measuring set.
- l. Delay distortion test set.
- m. Voltmeter, AC (db).
- n. Multimeter.
- o. Oscilloscope w/camera.

4. REFERENCES

- A. MIL-STD-188(-), Military Communication System Technical Standards
- B. TM 11-486, Electrical Communication Systems Engineering
- C. DCS Autodin Interface and Control Criteria, Defense Communications Agency, October 1967, AD-662-073
- D. Testing of Digital Data Transmission Systems, ECOM, February 1965, AD 614-775
- E. Comparative Performance Evaluation of Digital Data Modems for HF Radio, Air Force Systems Command, January 1965, AD 610-675
- F. Delay Distortion and Signal Impairment in Digital Data Transmission, Rand Corp., November 1967, AD 662-337
- G. Information Transfer Standards, System Development Corp., April 1966, AD 661-740
- H. Error Control for Digital Data Transmission Over Telephone Networks, Mitre Corp., May 1965, AD 616-678
- I. Error Performance of Differential Phase Shift Transmission Over a Telephone Line, Mitre Corp., August 1967, AD 658-437
- J. Speed Buffering and Digital Combining Techniques, ECOM, July 1967, AD 817-685
- K. HF Adaptive Modem Test, Collins Radio Co., May 1967, AD 815-855
- L. Richards, R. K., Electronic Digital Systems, John Wiley & Sons, 1966
- M. Bazovsky, Igor, Reliability Theory and Practice, Prentice-Hall, Inc., 1961

- N. Transmission Systems for Communications, Staff, Bell Telephone Laboratories, 3rd Edition, 1964
- O. Bennett and Davey, Data Transmission, McGraw-Hill, 1965
- P. MTP 3-1-002, Confidence Intervals and Sample Size
- Q. MTP 6-2-200, TDM-PCM Multiplexers
- R. MTP 6-2-507, Safety

5. SCOPE

5.1 SUMMARY

5.1.1 Technical Characteristics

The procedures outlined in this MTP describe in general terms the engineering tests required to evaluate the technical performance and characteristics of data channel terminal equipment and communication system/facilities with respect to their data transmission capability. To a certain extent, the tests are predicated on the use of special instrumentation comprising a data transmission test facility as described in Appendix B, however, individual components can be employed with appropriate adaptation.

The cumulative test results, along with the results of appropriate common engineering tests, will allow an estimate to be made of the degree of compliance of the item under test with applicable specifications and requirements, and the suitability of the item for service test.

The specific tests to be performed are divided into component (laboratory-type) and system (field) tests. These tests, and their intended objectives, are as follows:

- a. Component Tests - The objective of these tests is to determine the input-output and operating characteristics of a type data modem operating as the test item in a simulated data link.
- b. System Tests - The objective of these tests is to measure the capability of the test system to accurately and reliably handle digital data traffic in terms of data error rate and mean-error-free-interval with respect to time, data rate, and the system's inherent characteristics.

The closed-system and open-field tests are essentially identical. The closed-system tests are required as necessary to establish the effect of terminal equipment factors as a reference in determining the effect of the overall real-system variables.

5.1.2 Common Engineering Tests

The following Common Engineering Tests, applicable to these commodities, are not included in this MTP:

- a. 6-2-500, Physical Characteristics
- b. 6-2-502, Human Factors Engineering
- c. 6-2-504, Design for Maintainability
- d. 6-2-508, Electromagnetic Vulnerability

- e. 6-2-509, Electromagnetic Compatibility.
- f. 6-2-514, Electrical Power Requirements.
- g. 6-2-516, Adequacy of Shelter and Van Mounted Lighting, Ventilation, Air Conditioning and Heating Equipment.
- h. 6-2-520, Transportability of Communication, Surveillance, and Electronic Equipment.
- i. 6-2-530, Altitude and Temperature Altitude Test.
- j. 6-2-531, Temperature Test.
- k. 6-2-532, Sunshine Test.
- l. 6-2-533, Rain Test.
- m. 6-2-534, Humidity Test.
- n. 6-2-535, Fungus Test.
- o. 6-2-536, Salt Fog Test.
- p. 6-2-537, Dust Test.
- q. 6-2-538, Explosive Atmosphere Test.
- r. 6-2-539, Immersion Test.
- s. 6-2-540, Vibration Test.
- t. 6-2-541, Shock Test.

5.2 LIMITATIONS

This MTP excludes consideration of equipments which are designed or required solely to resolve ADP equipment anomalies or to perform ADP control functions external to a central processor or I/O device. Examples are:

- a. Speed buffers or modulation rate converters
- b. Error control systems
- c. Code converters
- d. Alphabet translators
- e. Special security devices

6. PROCEDURES

6.1 PREPARATION FOR TEST

a. Select test equipment ideally having an accuracy of at least ten orders of magnitude greater than that afforded by the item under test, that is in keeping with the state of the art, and with calibrations traceable to the National Bureau of Standards.

b. Record the following information:

- 1) Nomenclature, serial number(s), manufacturer's name, and function of the item(s) under test.
- 2) Nomenclature, serial number, accuracy tolerances, calibration requirements, and last date calibrated of the test equipment selected for the tests.

c. Ensure that all test personnel are familiar with the required technical and operational characteristics of the item under test, such as stipulated in Qualitative Materiel Requirements (QMR), Small Development Requirements (SDR), and Technical Characteristics (TC).

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d. Review all instructional material issued with the test item by the manufacturer, contractor, or government, as well as reports of previous similar tests conducted on the same types of equipment. These documents shall be kept readily available for reference.

e. Prepare record forms for systematic entry of data, chronology of test, and analysis in final evaluation of the test item.

f. Prepare adequate safety precautions to provide safety for personnel and equipment, and ensure that all safety SOP's are observed throughout the test and that the item has successfully completed MTP 6-2-507, Safety.

g. Thoroughly inspect the test item for obvious physical and electrical defects such as cracked or broken insulation, loose connections, bare or broken wires, loose assemblies, bent fragile parts, and corroded plugs and jacks. All defects shall be noted and corrected before proceeding with the test.

h. Prior to beginning any subtest, verify correct power source, necessary test instrumentation and inter-connecting cabling, and that the equipment is aligned, if necessary, as specified in the pertinent operating instructions to ensure, insofar as possible, it represents an average equipment in normal operating condition.

i. Prepare a test item sample plan sufficient to ensure that enough samples of all measurements are taken to provide statistical confidence of final data in accordance with MTP 3-1-002. Provisions shall be made for modification of the plan during test progress as may be indicated by monitored test results.

j. Ensure that arrangements for supporting and participating agencies, activities and facilities have been made, that authorization for electromagnetic radiation at specific frequencies, power levels and modulations for required periods has been obtained, that all personnel have been briefed on the purposes of the tests and the results expected, and that appropriate security measures are instituted, as required, to safeguard classified materiel and data.

6.2 TEST CONDUCT

NOTE: Modification of these procedures shall be made as required by technical design of the item under test and availability of test equipment, but only to the extent that such modified procedures will not affect the validity of the test results.

6.2.1 Component Tests

- NOTES:
1. These tests encompass the basic characteristics generally common to data modem equipment and shall be conducted in a laboratory-type environment. A data transmission test facility described in Appendix B may be utilized with the back configuration to provide the setup shown in Figure 1.
 2. The inputs and outputs of a generic data modem selected as a test item example for the purpose of test description are illustrated in Figure A-2.

6.2.1.1 Terminal Impedance

a. Prior to setting up the test items as shown in Figure 1, perform the following measurements on test items in a static condition (See Figure A-2):

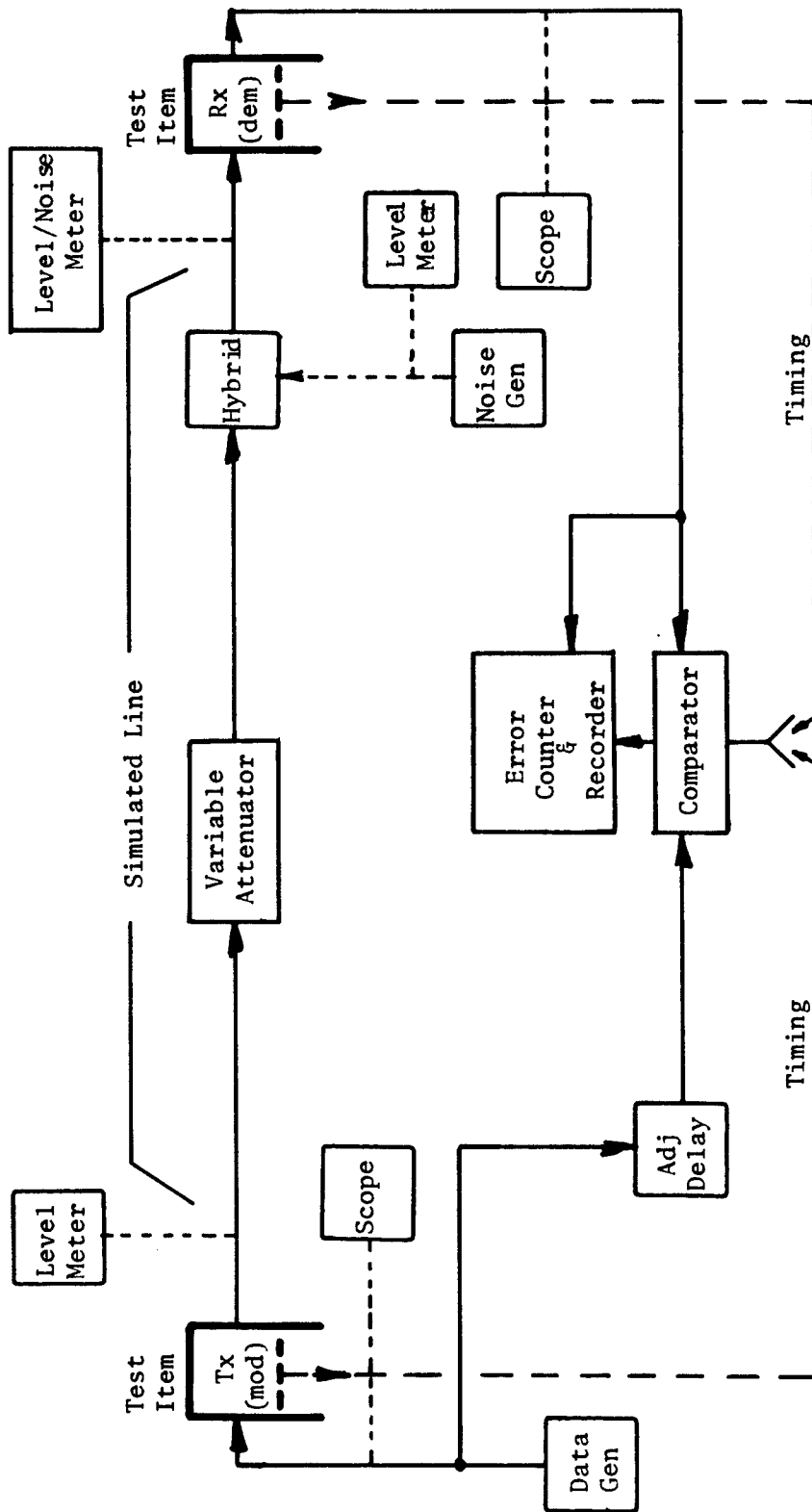


Figure 1. Generalized Component Test Setup.

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- 1) Measure the impedance of the transmitter output and receiver input (line side) with an impedance bridge or equivalent at selected test frequencies representative of the design line frequency band.
- 2) Measure the impedance of the timing source output at test frequencies commensurate with the test item bit rates.
- 3) Measure the capacitance and DC resistance of the DC data input(s) and output(s) (local side).

b. Record the following:

- 1) Line input and output channel impedance (Z_{θ} or $R + jX$) and the measurement frequencies.
- 2) Timing output channel impedance (Z_{θ} or $R + jX$) and the measurement frequencies.
- 3) DC resistance (ohms) and capacitance (pf) of each DC data input and output channel or subchannel.

6.2.1.2 Operating Parameters

- NOTES:
1. These tests shall be performed with the test items set up and operating as a simulated data link as shown in Figure 1.
 2. The data signal generator shall be programmed for a repetitive uniform bit pattern (alternate 1's and 0's) and operated at selected bit rates and a nominal output level.
 3. Data test signals shall be transmitted in blocks of established length (total bits) for each test for subsequent determination of error rate.

6.2.1.2.1 Timing - Determine Timing Signal Characteristics as follows:

- a. Measure the frequency and level of the reference timing output signal and check for stability over a minimal 14-hour period. Photograph an oscilloscope presentation of the waveform.
- b. Repeat Step a above, at each bit rate for which the test item is designed.
- c. Record timing signal frequency (Hz) and level (dbm) at each design bit rate at intervals (e.g. one hour) throughout the selected period. Include waveform photographs.

6.2.1.2.2 Transmitter Output Characteristics - Determine Transmitter Output Characteristics as follows:

- a. Measure the transmitter output power level (dbm) over the range of the output control (minimum, maximum and mid-range).
- b. Repeat Step a above, at each bit rate for which the test item is designed.
- c. Record the transmitter output level (dbm), and error rate information (number of bits in error/total bits transmitted) at each control setting and the composite data at each bit rate.

6.2.1.2.3 Line Signal Frequency Spectrum - Determine the Line Signal Frequency spectrum characteristics as follows:

- a. Determine the line signal frequency spectrum (output level at nominal mid-range) by scanning the line signal in frequency with a wave analyzer at the transmitter output, using maximum wave analyzer selectivity (minimum bandwidth). Measure amplitude at sufficient points between the lower and upper minimum measurable amplitude points to adequately describe the spectrum.
- b. Record line signal frequency spectrum data to include:

- 1) Transmitter composite output signal level (dbm).
- 2) Frequency (Hz) and signal level (dbm) at each selected frequency.
- 3) Wave analyzer selectivity (bandwidth) employed.

- c. Repeat Steps a and b above, at each bit rate for which the test item is designed.

6.2.1.2.4 Receiver Characteristics - Determine Receiver characteristics as follows:

- a. Measure the receiver sensitivity and dynamic range by varying the line signal level, as measured at the receiver input, in combination with the receiver gain control (if provided).

- b. Photograph oscilloscope presentations of the receiver output waveforms at selected points during Step a above, to depict the extent of output signal degradation with respect to a varying input.

- c. Record the following:

- 1) Received line signal level (dbm) at the selected points from minimum to maximum range.
- 2) Receiver gain control setting (if used) at each measuring point.
- 3) Error rate information obtained at each measuring point.
- 4) Waveform photographs correlated with 1), 2) and 3) above.

- d. Repeat Steps a, b and c above, at each bit rate for which the test item is designed.

6.2.1.3 Noise Tolerance

- NOTES:
1. This test shall be performed with the test items set up and operating as a simulated data link as shown in Figure 1.
 2. The data signal generator shall be programmed for a repetitive uniform bit pattern and operated at selected bit rates and a nominal output level.
 3. Data test signals shall be transmitted in blocks of established length for each test.

- a. Conduct a data transmission test without external noise to

establish a reference error rate with a constant nominal received signal level, e.g. -10 dbm.

b. Repeat Step a above, in a series with random noise added in increments to produce signal-plus-noise-to-noise (S/N) ratios in steps ranging for example, from 40 db to 5 db.

NOTE: For the random noise, a random (white) noise generator shall be used which has a flat power density spectrum equal to or greater than the frequency band of interest as determined in paragraph 6.2.1.2.3 a.

c. Photograph oscilloscope presentations of the receiver output (DC) signal at S/N ratios selected to correlate signal degradation with increasing error rate.

d. Record the following:

- 1) Received line signal level (dbm)
- 2) Noise generator output levels (dbm)
- 3) S/N ratio (db)
- 4) Error rate information at each S/N
- 5) Waveform photographs
- 6) Noise signal characteristics

e. Repeat Steps b, c and d above, at each bit rate for which the test item is designed.

f. Repeat Steps b, c, d and e above, utilizing an impulse noise generator which has output characteristics (pulse duration, repetition rate, polarity) commensurate with the data test signals or specific test requirements; amplitude shall be the effective (rms) value measured by the level meter in dbm.

6.2.2 System Tests

- NOTES:
1. System tests are based essentially on two correlated subtests, i.e., measurement of channel electrical characteristics and measurement of data transmission in terms of the error characteristics. For test description purposes, the simplified system of Figure 2 represents the essential elements-terminals/stations, path, and derived data channels of typical systems. In this context, nominal 4KHz analog channels are assumed; data modems are included in the Data Transmission Test Facility (DTF) (Appendix B).
 2. Reference is made to MTP 6-2-200, PCM Multiplexers for methods of circuit quality measurement, particularly as applied to multi-channel systems.
 3. All test data recordings shall include real time in code in order to effect precise correlation of events in subsequent analyses.

6.2.2.1 Closed System (back-to-back) Tests

a. Collocate and connect the system terminals/stations back-to-back as represented by the simulated path of Figure 2.

b. Perform the following standard transmission (circuit quality) measurements on the data channel(s) with the noise source inoperative and the attenuation at a minimum to avoid overloading the receive terminal.

- 1) Frequency response (loss versus frequency)
- 2) Envelope delay distortion
- 3) Total harmonic distortions
- 4) Circuit noise
- 5) Crosstalk (multi-channel system)

c. Record the following:

- 1) Frequency response data in tabular form consisting of the received test tone level (dbm) measured at each test frequency.
- 2) Envelope delay test data in tabular form showing the delay, in microseconds, measured at the incremental test frequencies.
- 3) Total harmonic distortion test data in tabular form showing for each test frequency, the measured signal + distortion and distortion only levels, both in dbm.
- 4) Circuit noise level in dbm. Test data shall include the line weighting and specific type of noise measuring set employed.
- 5) Crosstalk test data consisting of the signal + crosstalk and the crosstalk only levels (dbm) measured in each selected channel combination.

d. With the equipment set up as in Step a above, adjust and maintain input and output data channel signal levels to the nominal system operating levels (output level = test signal plus circuit noise), and conduct data transmission tests by transmitting data test signals.

- NOTES: 1. Transmissions shall be made in "test blocks" to test lengths in accordance with Appendix C.
2. Tests shall be conducted at each bit rate indicated by the type of test item and/or test directive.

e. During the performance of Step d above, re-run circuit quality measurements (Step b) as often as necessary to detect variations and when investigating unacceptable test results (Appendix C).

f. Record the following at each test bit rate:

- 1) Test transmission rate (bits/second)
- 2) Test length in terms of time and total bits transmitted
- 3) Bit-by-bit chronological error record
- 4) Correlative circuit quality deviations

g. Following the test run at each bit rate, compute and record the signal-plus-noise-to-noise ratio of the receive channel levels measured in Step d above.

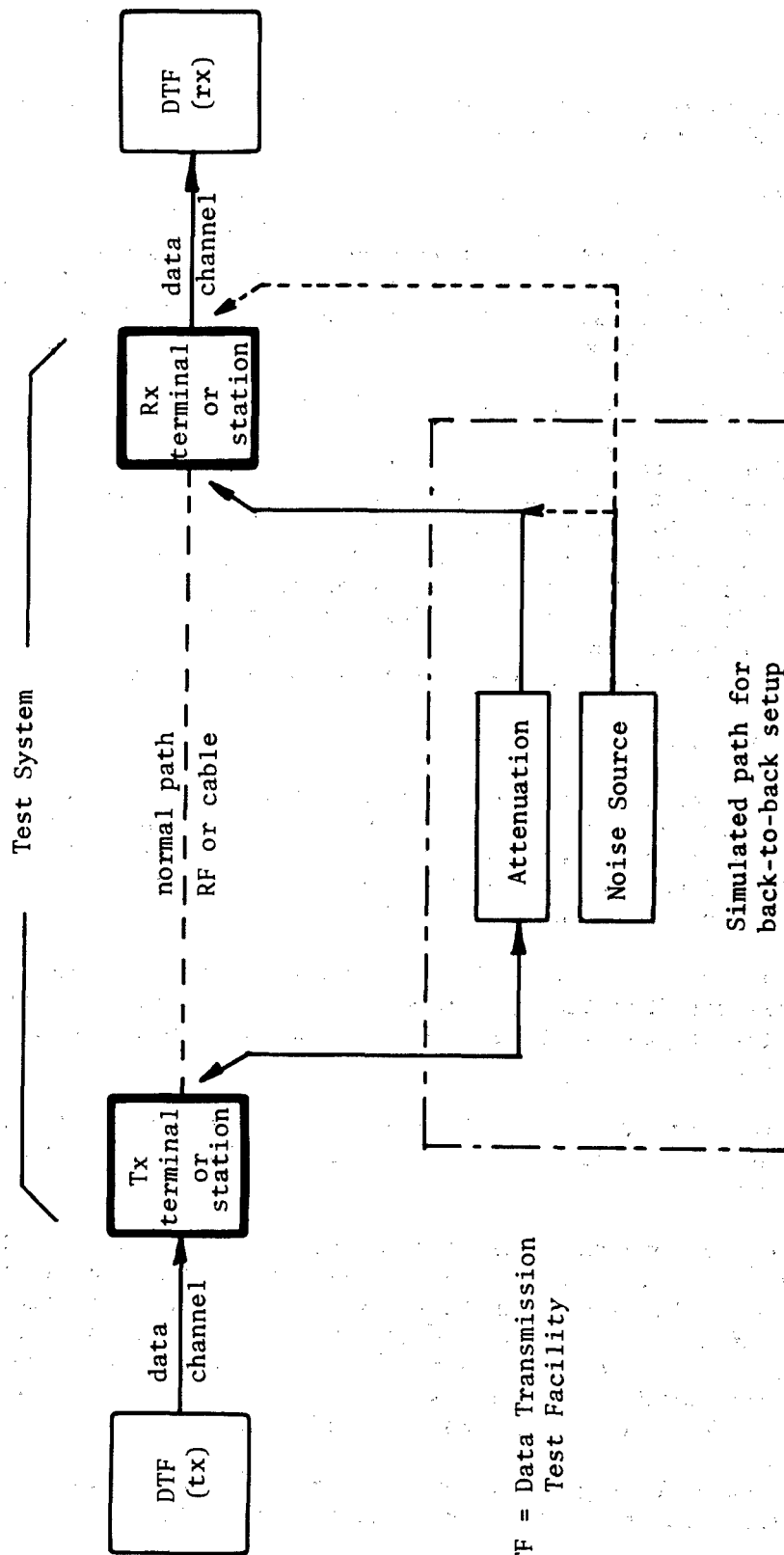


Figure 2. Simplified System Test Setup.

h. Repeat Steps d through f above, for noise tests described in paragraph 6.2.1.3 modified as follows:

- 1) Introduce the random and impulse noise, in turn, at a point appropriate to the test system (Figure 2).
- 2) Adjust the noise level in discrete steps to produce receive S/N ratios in decrements (e.g. 5 db) from the value(s) determined in Step g above, to the S/N value at test truncation (Appendix C).

i. Record the following at each test bit rate:

- 1) Test transmission rate (bit/second).
- 2) Test length in terms of time and total bits transmitted.
- 3) Bit-by-bit chronological error record.
- 4) Correlative circuit quality deviations.
- 5) Data S/N ratio with no external noise.
- 6) Decremental data S/N ratios - random noise.
- 7) Decremental data S/N ratios - impulse noise.
- 8) Error rate at each data S/N ratio, 5), 6), and 7) above.

6.2.2.2 Open-Field System Tests

a. Install tactical communication system/facilities that are designated as test items for data transmission tests in a field environment with the terminals/stations deployed at realistic system ranges selected to provide maximum fade margin and near maximum S/N ratio. General test set up shall be as shown in Figure 2 (normal path).

NOTE: Due to the widely differing system characteristics and possible configurations, test set ups and preparations shall be dictated by the type of system and available support facilities.

b. Ensure, insofar as practicable, system test configurations include ancillary facilities such as remote operation equipments, patch, panels, and terminal wire and cable.

NOTE: Data modems required to terminate system test channels, but which in themselves are not test items, shall be selected on the basis of compatibility with the test channels and compliance with test requirements. In the event a communication system/facility and a specific data modem are both designated as test items of an integrated test, test procedures and results shall be differentiated as required.

c. Conduct circuit quality and data transmission tests as outlined in paragraph 6.2.2.1 with applicable modifications as follows:

- 1) Omit the stepped S/N tests of paragraph 6.2.1.3 using ex-

ternal noise sources.

- 2) All radio system tests shall include a continuous RF signal strength measurement and recording at the receiving site, correlated in real time with other test events.
- 3) Tests of systems employing SSB modulation, i.e. radio or frequency-division-multiplex (FDM) systems, shall include a channel frequency shift (frequency translation) measurement over the band of interest.
- 4) Systems in which one terminal is normally or may be in motion during real test transmission shall be tested in typical configurations to determine the effect of Doppler shift on data transmission accuracy. Airground and tactical vehicular communication systems are in this category. Controlled test conditions shall include variation of range, speed and direction of travel of the moving terminal with respect to the fixed terminal during the data transmissions.

d. Record the following:

- 1) All items required in paragraph 6.2.2.1 (except the decremental S/N noise test).
- 2) Chart recording of RF signal strength versus real time (if applicable).
- 3) Profile diagrams of RF paths (if applicable).
- 4) Meteorological conditions (as applicable).
- 5) Channel frequency translation (\pm Hz) at the selected test frequencies (SSB systems), as applicable.
- 6) Doppler shift test data (as applicable) to include detailed information on the terminal positions and direction and rate of travel correlated precisely with the data transmission test data.

6.3 TEST DATA

6.3.1 Preparation for Test

Data to be recorded prior to testing shall include but not be limited to:

- a. Nomenclature, serial number(s), manufacturer's name, and function of the item(s) under test.
- b. Nomenclature, serial number, accuracy tolerances, calibration requirements, and last date calibrated of the test equipment selected for the tests.
- c. Damages to the test item incurred during transit and/or manufacturing.

6.3.2 Test Conduct

Data to be recorded in addition to specific instructions listed below for each subtest shall include:

a. A block diagram of the test setup employed in each specified test. The block diagram shall identify by model and serial number, all test equipment and interconnections (cable lengths, connectors, attenuators, etc.) and indicate control and dial settings where necessary.

b. Photographs or motion pictures (black and white or color), sketches, charts, graphs, or other pictorial or graphic presentation which will support test results or conclusions.

c. An engineering logbook containing, in chronological order, pertinent remarks and observations which would aid in a subsequent analysis of the test data. This information may consist of temperatures, humidity, pressures, and other appropriate environmental data, or other description of equipment or components, and functions, and deficiencies, as well as theoretical estimations, mathematical calculations, test conditions, intermittent or catastrophic failures, test parameters, etc., that were obtained during the test.

d. Test item sample size (number of measurement repetitions).

e. Instrumentation or measurement system mean error stated accuracy.

6.3.2.1 Component Tests

6.3.2.1.1 Terminal Impedance -

Record the following:

a. Line input and output channel impedance (Z_{θ} or $R + jX$) and the measurement frequencies.

b. Timing output channel impedance (Z_{θ} or $R + jX$) and the measurement frequencies.

c. DC resistance (ohms) and capacitance (pf) of each DC data input and output channel or subchannel.

6.3.2.1.2 Operating Parameters -

Record the following:

a. Timing signal frequency (Hz) and level (dbm) at each design bit rate at intervals throughout the selected period. Include waveform photographs.

b. Transmitter output level (dbm), and error rate information at each control setting and the composite data at each bit rate.

c. Line signal frequency spectrum data to include:

- 1) Transmitter composite output signal level (dbm).
- 2) Frequency (Hz) and signal level (dbm) at each selected frequency between minimum measurable amplitude points.
- 3) Wave analyzer selectivity (bandwidth) employed.

d. Receiver characteristics test data to include:

- 1) Received line signal level (dbm) at the selected points from minimum to maximum range.
- 2) Receiver gain control setting (if used) at each measuring point.

- 3) Error rate information obtained at each measuring point.
- 4) Waveform photographs correlated with the test data of 1), 2), and 3) above.

6.3.2.1.3 Noise Tolerance -

Record the following for the noise tests (random and impulse) conducted at each bit rate:

- a. Received line signal level (dbm)
- b. Noise generator output levels (dbm)
- c. S/N ratio (db)
- d. Error rate information at each S/N
- e. Waveform photographs
- f. Noise signal characteristics

6.3.2.2 System Tests

6.3.2.2.1 Closed System Tests -

Record the following closed system (back-to-back) test data:

a. Circuit quality measurements to include:

- 1) Frequency response data in tabular form consisting of the received test tone level (dbm) measured at each test frequency.
- 2) Envelope delay test data in tabular form showing the delay, in microseconds, measured at the incremental test frequencies.
- 3) Total harmonic distortion test data in tabular form showing for each test frequency, the measured signal + distortion and distortion only levels, both in dbm.
- 4) Circuit noise level in dbm. Test data must include the line weighting and specific type of noise measuring set employed.
- 5) Crosstalk test data consisting of the signal + crosstalk and the crosstalk only levels (dbm) measured in each selected channel combination.

b. Data transmission test data to include the following at each test bit rate:

- 1) Test transmission rate (bits/second)
- 2) Test length in terms of time and total bits transmitted
- 3) Bit-by-bit chronological error record
- 4) Correlative circuit quality deviations
- 5) Data S/N ratio with no external noise
- 6) Incremental data S/N ratios - random noise
- 7) Incremental data S/N ratios - impulse noise
- 8) Error rate at each data S/N ratio, 5), 6), and 7) above

6.3.2.2.2 Open-Field System Tests -

Record the following for the open-field system tests:

- a. All items required in paragraph 6.3.2.2.1 (except the decremental S/N noise test).
- b. Chart recording of RF signal strength versus real time (if applicable).
- c. Profile diagrams of RF paths (as applicable)
- d. Meteorological conditions (as applicable)
- e. Channel frequency translation (\pm Hz) at the selected test frequencies (SSB systems), as applicable.
- f. Doppler shift test data (as applicable) to include detailed information on the terminal positions and direction and rate of travel correlated precisely with the data transmission test data.

6.4 DATA REDUCTION AND PRESENTATION

Processing of raw test data shall, in general, consist of organizing, marking for identification and correlation, and grouping the test data according to subtest title. Test criteria or test item specifications, where required, shall be noted on the test data presentation to facilitate analysis and comparison. Where necessary, test data measurements shall be converted to be compatible with units given by test criteria or specifications.

Primary test data shall be reduced by the most advantageous means and methods available; for example, the computer section of a data transmission test facility (Appendix B) may be configured and programmed to provide some on-line computations and also be used for post-test-run data processing.

Specific instructions for the reduction and presentation of individual subtest data are outlined in the succeeding paragraphs.

6.4.1 Component Tests

- a. Impedance, timing, and level range test data shall be presented in tabular form accompanied by annotated waveform photographs.
- b. Line frequency spectrum data shall be presented as a graph of data line signal amplitude versus frequency.
- c. Noise tolerance data shall be presented as a graph of error rate versus S/N ratio for each bit rate.

6.4.2 System Tests

a. Test data resulting from the closed-system and open-field tests may be presented separately or where the subtests in each configuration are comparable the two sets of test data may be combined in one graph and/or table to point up the effects of the real transmission path on data transmission quality.

b. Test data resulting from a series of circuit quality measurements made during one complete test shall be reduced to one graph/table for each channel parameter showing the mean values, the maximum deviations from mean,

and the number of observations. In the event variation of any one parameter value has caused a degradation of data transmission quality, this data shall be presented separately, e.g., error rate variation versus the parameter variation.

c. Data transmission test data shall be reduced to provide the following information appropriate to each test or subtest.

- 1) Total bits transmitted
- 2) Total bits in error

3) Error rate = $\frac{\text{total bits in error}}{\text{total bits transmitted}}$

4) Mean error free interval (bits) = $\frac{\text{total bits transmitted}}{\text{total bits in error}}$

- 5) Mean burst length (bits)
- 6) Total number of bursts
- 7) Mean interval between bursts (bits or time)

In addition to a statement of the above test results, data presentation may be made in a number of ways dependent upon test requirements and nature of the test and test item with the principal objective of depicting the relationship between any given data parameter and the test item characteristic or fortuitous variables. For example: error rate versus transmission (bit) rate; interval between bursts versus RF signal conditions; correlation of impulse noise and single-bit or burst errors; error rate versus S/N ratio.

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APPENDIX A

DATA TRANSMISSION EQUIPMENT

Figure A-1 depicts the elements and interconnections of a segment of a hypothetical tactical ADP system. The number and quality of data channels in each path is primarily dependent upon the tactical importance (priority) of the data messages, the volume of data traffic, and the type of available communication facilities. With suitable interface equipment employed at terminals, data channels may be established on the existing tactical communication systems/facilities, e.g., wire and cable (metallic and multiplexed) and net, point-to-point, and multiplexed radio systems.

The demand for higher information transfer rates to meet data user requirements and to fully realize ADP system capabilities, coupled with the need for more efficient voice channel utilization and the availability of wideband/high-speed channels, has necessitated the development of more sophisticated modulation-demodulation methods. In recent years several methods have been developed and implemented in efforts to attain the following general objectives to an optimum degree.

- a. High data rates
- b. Low error rate
- c. Range of optional rates
- d. Adaptability to different transmission media or channel bandwidths.
- e. Tolerance to transmission path impairments.

Modulation methods have included amplitude-, frequency-, and phase-modulation or keying of one or more audio frequencies with the information bearing DC digital signals. Of these methods, phase-modulation (phase shift keying/PSK) in various forms is generally conceded to be the leading method. One example of PSK is termed quaternary phase shift modulation wherein the DC digital data is sampled in two-bit groups and the combination of either a 11, 01, 00, or 10 causes a respective phase shift of 45, 135, 225, or 315 degrees of an audio "carrier" tone. At the receiver, bit-pair signals are recognized by phase comparison with preceding signals and subsequently demodulated to DC digital signals representing the original signals. Such a method is said to be differentially coherent, i.e., deriving synchronization with the transmitter from the received signals rather than a separately transmitted or generated reference signal.

In order to achieve higher data rates or provide diversity operation, a refinement of the above technique employs a number of parallel frequency-divided tones (as in multiplex telegraphy), each of which are quaternary phase shift modulated.

Figure A-2 illustrates an example of basic data modem and some of the salient aspects.

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The advent of PCM-TDM multi-channel systems (reference MTP 6-2-200) and their capability of handling high speed data without digital-analog conversion has necessitated the development of equipment to perform the ADP-communications interface function. This is somewhat comparable to a voice-channel data modem in that it is required by the transmission system. Described briefly, the basic component, known currently as a "high speed data buffer" can accept a high-speed data pulse train from ADP equipment or other source and inject the data pulses, "N" bits at a time, into a vacated voice-channel time slot of the PCM-TDM system pulse train. The receiving section of the distant terminal buffer accomplishes the reverse or recovery process. A companion component, termed a "low-speed data buffer", performs a data multiplexing function as well as rate conversion. It can accept several discrete low-to-medium-speed DC data channels from different sources and reproduce the combined data as a high speed serial pulse train for input to the high-speed data buffer. The receiving buffer accomplishes the demultiplexing process.

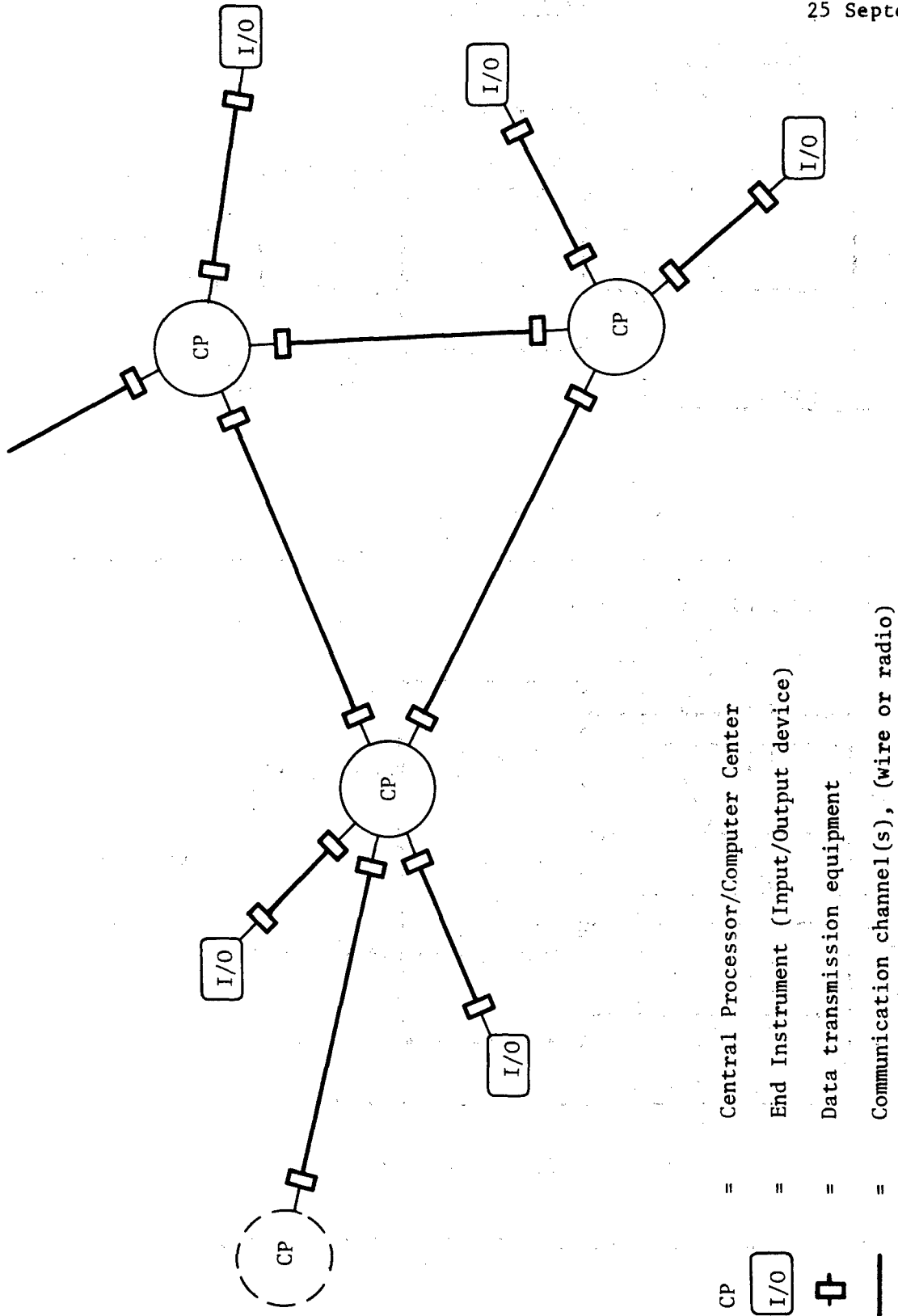
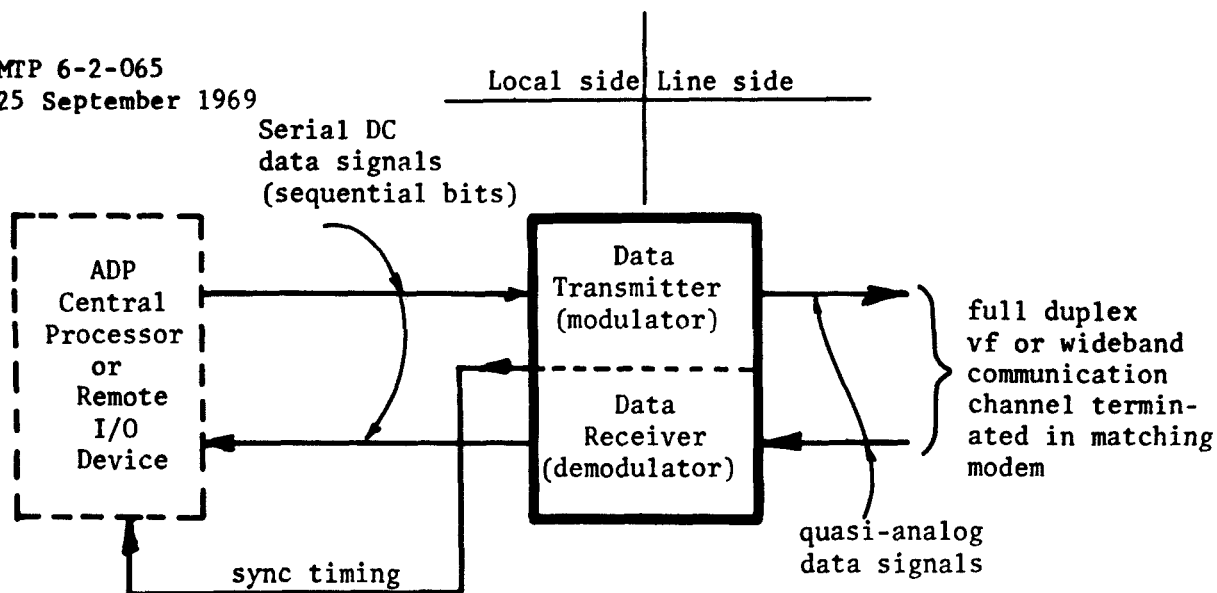
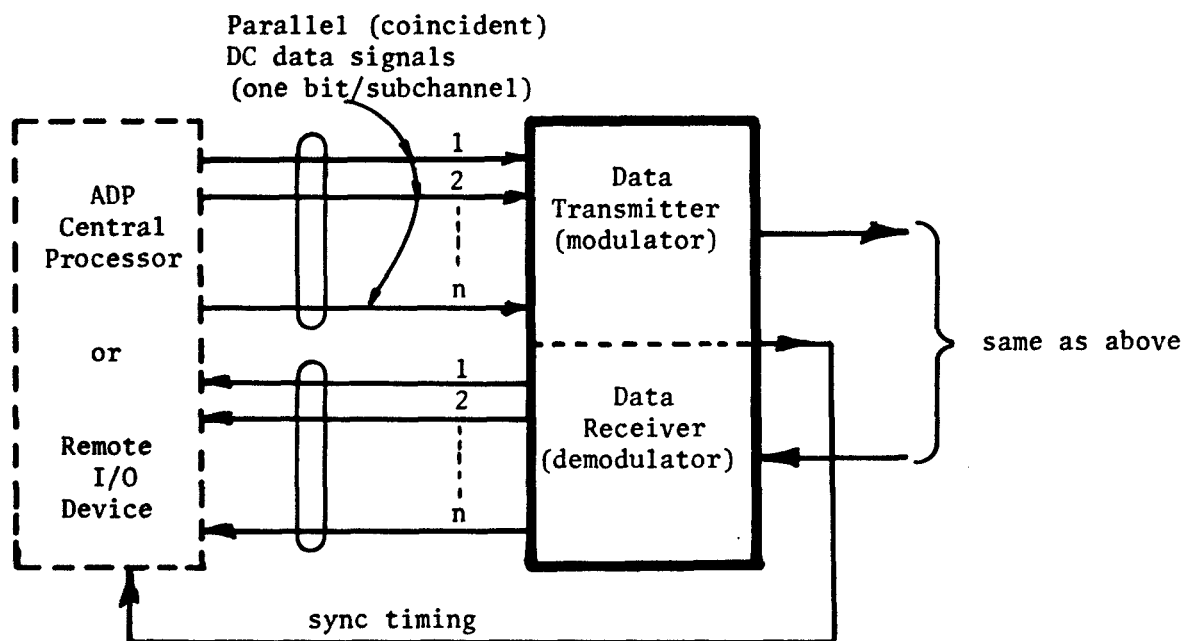


Figure A-1. Segment of Hypothetical Tactical ADP System

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a. Serial ADP Input/Output



b. Parallel ADP Input/Output

Figure A-2 Basic Characteristics of Type Data Modems.

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APPENDIX B

DESCRIPTION OF A DATA TRANSMISSION TEST FACILITY

The "data transmission test facility" listed in paragraph 3 consists of locally assembled instrumentation complexes (transmitting and receiving). Major functions are:

a. Conventional transmission (circuit quality) measurements of communication channels proposed for data transmission.

b. Determination of overall data channel quality by measurement and analysis of actual data transmissions, i. e. rate, characteristics, and distribution of errors in received test transmissions.

To facilitate point-to-point testing of long-range communication systems, separate mobile transmitting and receiving units are preferred. The transmitting unit shall include standard test equipment items for (1) straightaway transmission measurements, (e. g. signal and noise generators, frequency counters, oscilloscope, delay test set) and (2) a digital signal/pattern generator with modems (standard or test item) for generating data test signals. The receiving unit shall include but not be limited to (1) test equipment for the basic channel measurements, (e. g. level meter, distortion analyzer, delay test set) and (2) compatible modems, real-time clock, digital pattern generator (identical to transmitter), error count subsystem, computer subsystem, and recording subsystem for analysis of received data signals. An RF field strength measuring system is required additionally for correlation of radio path vagaries with received data test signals, although multi-hop systems introduce many unknown factors.

A multi-channel magnetic tape recorder/reproducer is employed to simultaneously record the received test pattern, test events, RF signal, and real-time code with provision for rapid search for and play-back of specific recorded test intervals.

In a typical test operation involving, for example, a point-to-point communication link, the test channel characteristics are first measured and recorded. The transmitting unit is then setup to send data test signals in a definite pattern at a prescribed rate. The receiving unit operates on the received test pattern in a number of ways to determine the extent and characteristics of any degradation imposed by the test channel. Correlation of data, events, and processing operations is in real-time.

Described briefly, the received test pattern is compared bit-by-bit with an identical test pattern generated within the receiving unit. A determination is made that each received bit is either correct, incorrect as a "1" to "0" transition, or incorrect as a "0" to "1" transition. The information is displayed, processed, and stored in a manner to provide a complete record of all correct and incorrect bits in the sequence of occurrence. The received pattern is examined in intervals of one second and a record maintained of the total error-free one-second intervals. The test instrumentation is further configured, programmed and employed to

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analyze the test data either during or subsequent to a test run and to provide information in printed or punched tape form, typical of the following:

- a. Cumulative total of bits transmitted.
- b. Cumulative total of bits in error.
- c. Cumulative total of error bursts (burst: two or more consecutive bits in error)
- d. Cumulative total of correct bits received.
- e. Maximum, minimum, and mean interval (bits) between bursts.
- f. Error rate $\frac{\text{total bits in error}}{\text{total bits transmitted}}$
- g. Total 1-second intervals
- h. Percent of error-free 1-second intervals.

APPENDIX C

RATIONALE FOR DETERMINATION OF TEST PERIODS AND APPLICABILITY

Establishment of data transmission test and subtest periods having a certain flexibility with respect to duration and applicability is essential to ensure adequate test results within practical limits and to preclude excessive testing time. Determination of these factors is influenced primarily by the test item type and concept of employment and the specified accuracy criteria.

The procedure described herein determines overall test length by progressively measuring test results against a specified criteria. Initially, a basic time period (test block) for test signal transmissions must be established for general classes of test item, i. e. the basic test signal transmission period should be approximately proportional to the test item's anticipated or planned data traffic. For example, data traffic via FM voice radio nets and HF-SSB point-to-point radio circuits is characterized by short message length and/or transmission periods; hence, a test block of 10 - 15 minutes may be sufficient for test items of these types. On the other hand, multi-channel radio and cable systems can provide full-time channels for high volume data traffic and therefore, as test items, require a proportionately longer test block for adequate testing, e. g. one hour.

The procedure is based on a "constant confidence level sequential test" for an exponential failure distribution (Reference 4.M.). The procedure defines accept, reject, and continue testing regions for a given criterion of mean-bits-between-errors (MBBE) on a graph of total accumulated number of bits versus number of errors.

These regions are:

1. Accept if $N \geq \frac{1}{2} N_0 \chi^2_{.10; 2\gamma + 2}$
2. Reject if $N \leq \frac{1}{2} N_0 \chi^2_{.90; 2\gamma}$
3. If $\frac{1}{2} N_0 \chi^2_{.90; 2\gamma} < N < \frac{1}{2} N_0 \chi^2_{.10; 2\gamma + 2}$ continue

testing unless $N \geq N_{\text{truncation}}$, at which time stop the test and calculate the 90-percent confidence interval on the true MBBE (μ):

$$\mu \geq \frac{2N}{\chi^2_{.10; 2\gamma + 2}}$$

where N = Number of bits transmitted (total)
 N_0 = Criterion MBBE

γ = Number of errors (total)

$\chi^2_{p;q}$ = the p-percentile of the Chi-Squared distribution for q degrees of freedom.

The following three methods and their associated graphs illustrate the use of the procedure for tests involving different MBBE criteria and test truncation points.

Method A - At the end of each testing block, the accumulated total number of errors and the accumulated total number of bits transmitted will be checked against the statistical curves in Figure C-1 for a mean-bits-between-errors or error burst (MBBE) of 1×10^6 bits and a maximum test length of 1×10^7 bits. The test will be terminated if the intersection of the number of errors and bits transmitted falls within the "accept" or "reject" region. If the results fall within the "continue testing" region, testing will resume and the same checks will be made at the end of each block of testing. However, if the results do not fall in either "accept" or "reject" by the time 10 million bits have been transmitted, the test will be terminated at 10 million bits and the true MBBE calculated. If the results fall in the "reject" region, the system will be checked for malfunction and the test repeated.

Method B - This method is the same as Method A except that the MBBE criterion is 1×10^5 bits and the maximum test length is 1×10^6 bits. The curves in Figure C-2 will be used.

Method C - This method is the same as Method A except that the MBBE criterion is 1×10^5 bits. The maximum test length remains at 1×10^7 bits. The curves in Figure C-3 will be used.

Selection of a method for any given class or type of test item will be governed principally by the following factors:

- a. Specified MBBE criteria.
- b. Data (bit) rate, design or anticipated.
- c. Transmission media characteristics such as radio propagation variables versus time.

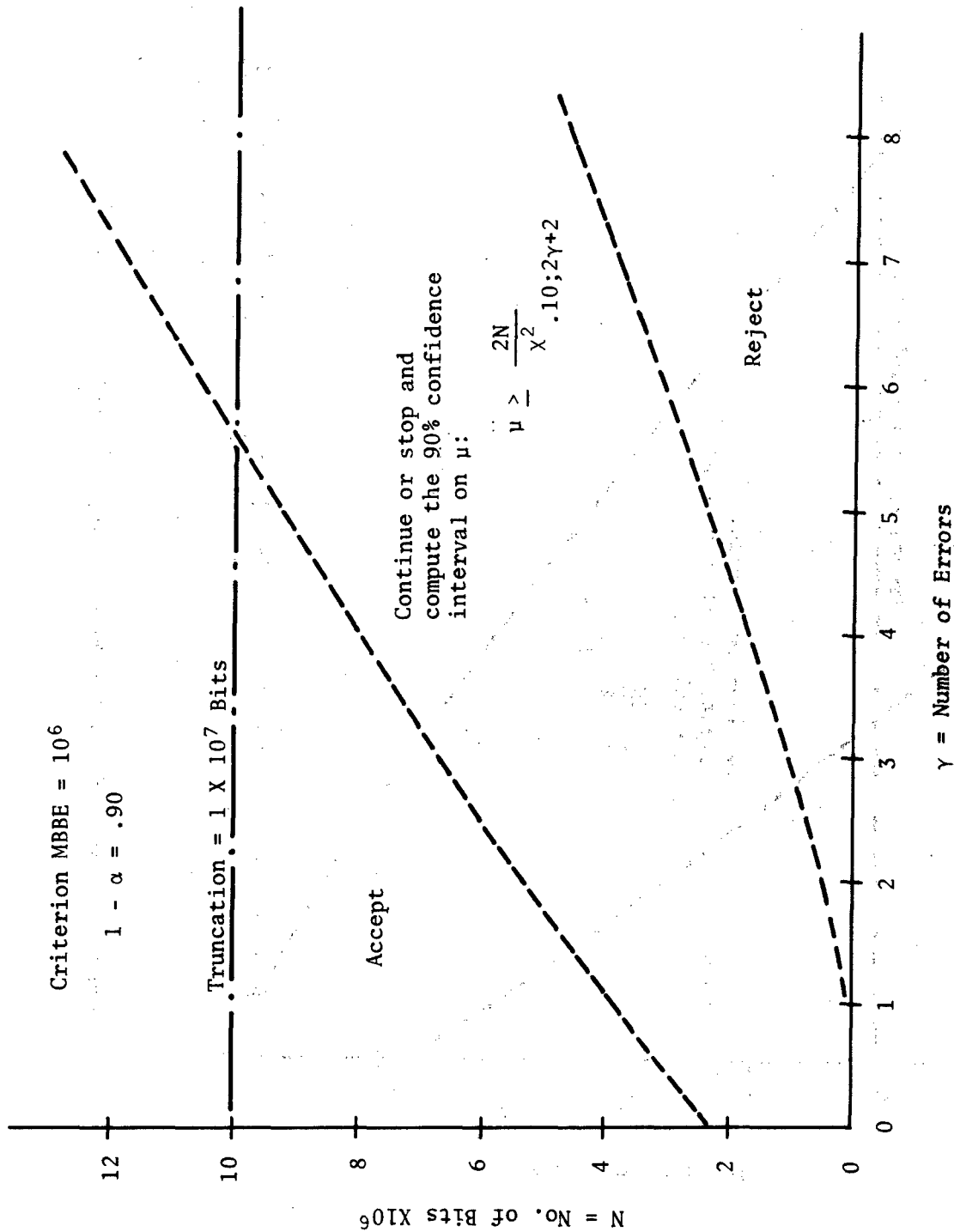


Figure C-1: Data Transmission Test Length Criteria - Method A.

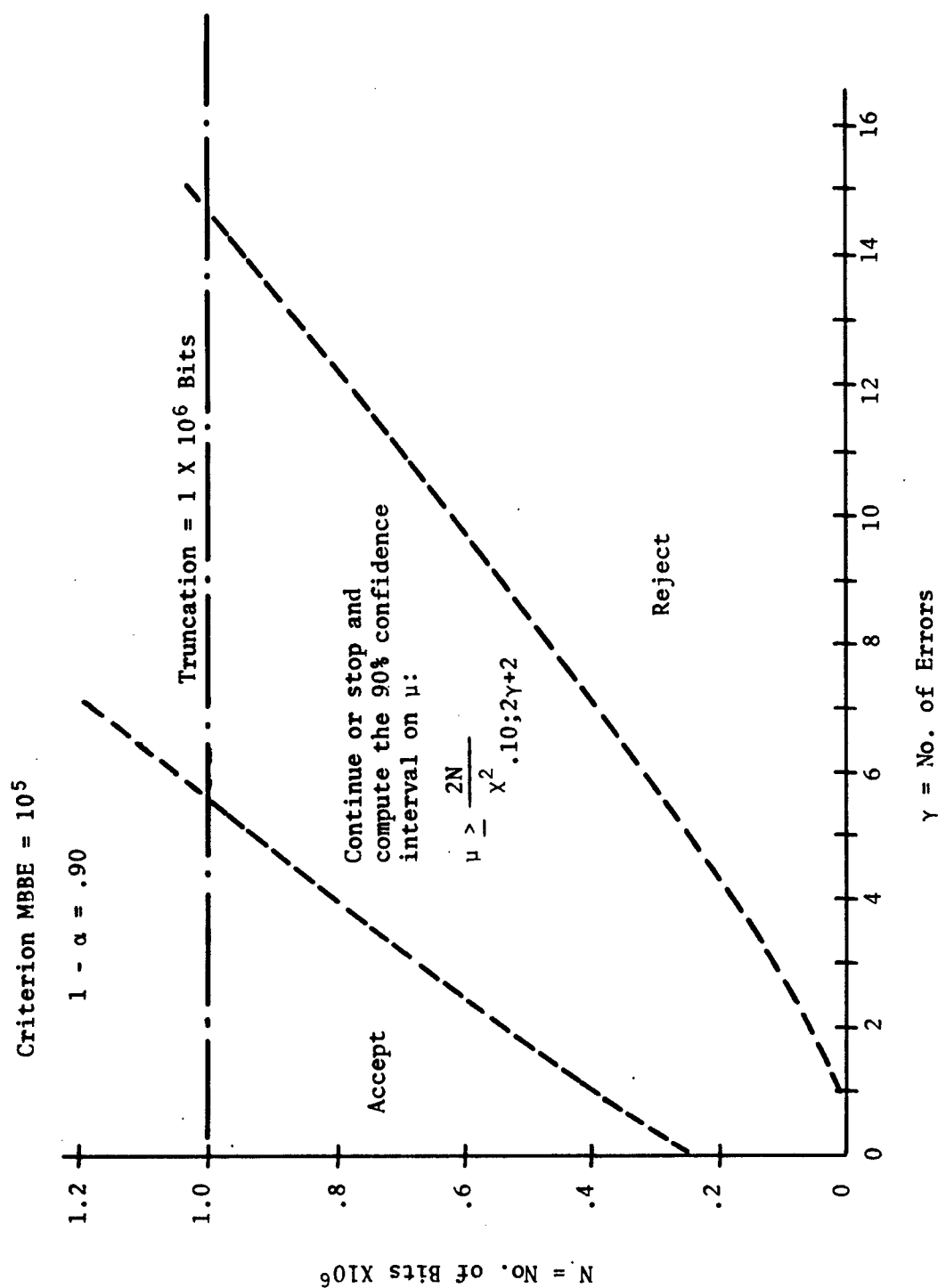


Figure C-2. Data Transmission Test Length Criteria - Method B.

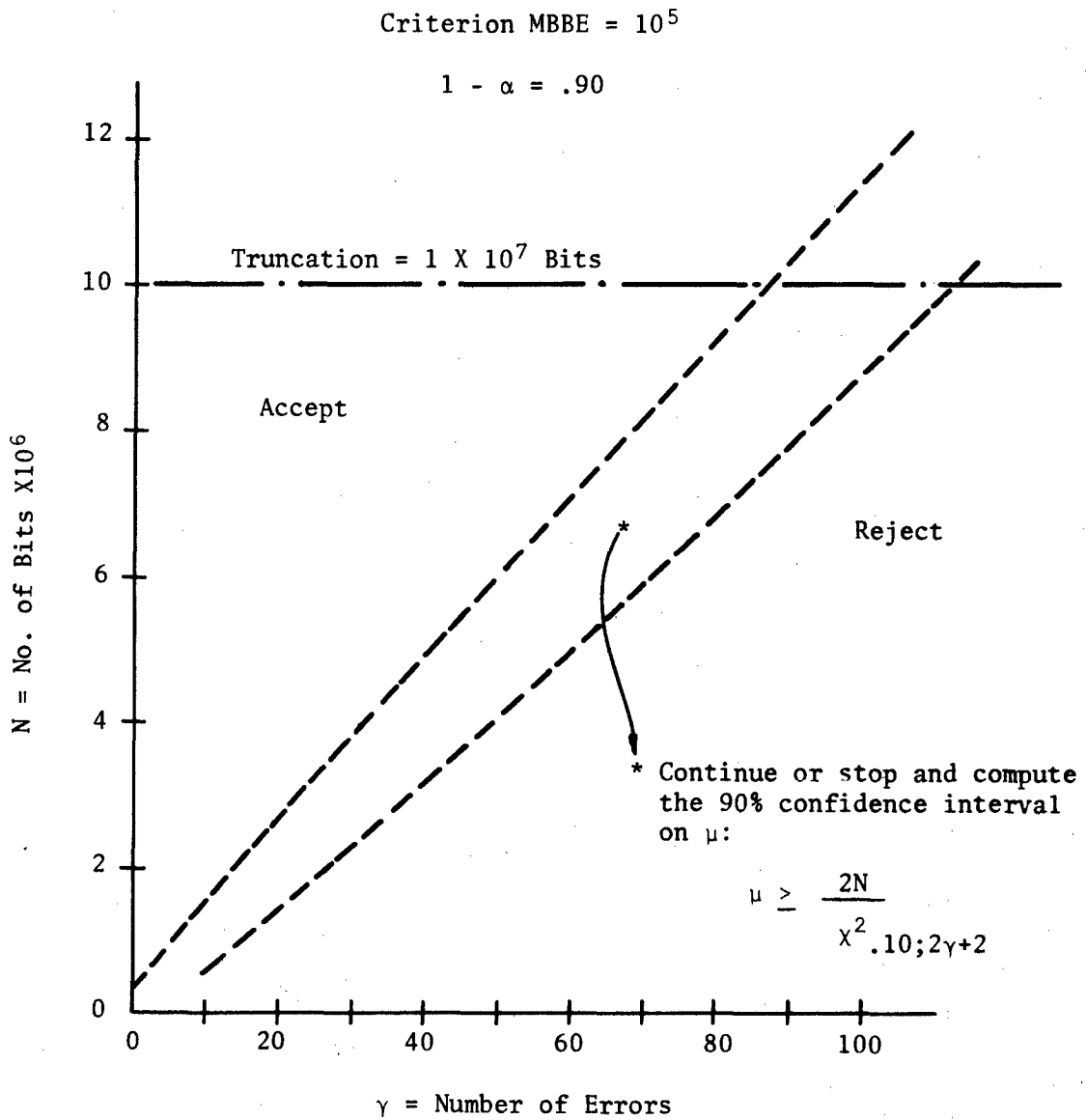


Figure C-3. Data Transmission Test Length Criteria - Method C.